Taylor Engineering
LLC
1080 Marina Village Parkway, Suite 501 ■ Alameda, CA 94501-1142 ■ (510) 749-9135 ■ Fax (510) 749-9136

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Aniruddh Roy
Air-Conditioning and Refrigeration Institute
2111 Wilson Boulevard, Suite 500
Arlington, VA 22201-3001, USA

Subject: Title 24 Fan Control and Integrated Economizer Proposal

Dear Aniruddh:

Thank you for your comments on the Title 24 Fan Control and Integrated Economizer Proposal, for your alternate proposal, and for your offer to work together to develop a consensus proposal. Along those lines, we have modified the proposal to bring it more in line with your alternate proposal.

Below we respond in detail to your comments. In summary, you make some valid points but the fundamental issue remains: if the actual compressor load is less than the lowest stage of capacity and the compressor has a minimum runtime then either the economizer will have to be limited and/or the supply air temperature will go well below setpoint, which will result in unnecessary latent cooling, risk of coil freezing, degraded compressor efficiency and poor comfort. This basic physical mechanism cannot be prevented without sufficient turndown, even with the most sophisticated control algorithms. Limiting the economizer results in excessive damper movements and premature economizer failure. The most efficient way to address this problem is to have finer increments of cooling capacity control so that the capacity available at any moment more closely matches the actual load at that moment. It is quite common to have real compressor loads below 10% of the total compressor capacity, particularly with integrated economizers, internally load dominated buildings, and oversized air conditioners.

We did not see any real substantive difference between your alternate proposal and our original proposal for chilled water units or for fan control of DX units. The real difference comes down to the integrated economizer proposal for DX units. Our original proposal calls for 20% turndown starting in 2015. The AHRI alternate proposal calls for 50% turndown for single zone units and 25% turndown for multiple zone units starting now for 6 to 9 tons and starting in 2015 for 10 tons and above. This alternate proposal for DX turndown will result in less energy savings because most if not all 2 speed/variable speed single zone units over 5 tons will already have 2 stages of capacity and most large multiple zone units will already have 4 stages of capacity.

The revised proposal below is a compromise between these two positions. The turndown requirements are set to the AHRI proposed levels until 2018. After 2018 the turndown requirements become stricter. We hope you will agree that this is a reasonable compromise and

an important step to address the fundamental problem of compressor over-capacity in economizer mode and provide truly efficient, integrated economizer operation.

Revised Proposal

Changes to the original proposal are highlighted in red below:

2. If an economizer is required by Subparagraph 1, it shall be:

   B. Capable of providing partial cooling even when additional mechanical cooling is required to meet the remainder of the cooling load. Effective January 1, 2015, direct expansion systems with a cooling capacity ≥ 65,000 Btu/hr[a] shall ~~be capable of staging or modulating capacity in increments of no more than 20% of total cooling capacity. .~~ have mechanical capacity control that is interlocked with the economizer control such that the economizer does not begin to close until the unit leaving air temperature is less than 45°F. Direct expansion systems shall also be capable of staging or modulating capacity in increments of no more than those listed in Table X. Controls shall not false load the mechanical cooling system by limiting or disabling the economizer or any other means, such as hot gas bypass, except at the lowest stage of cooling capacity.

Table X – Effective Date of Lowest Stage of Cooling Capacity

System Type	DX Cooling Capacity[a]	Lowest Stage of Cooling Capacity	Effective Date
Single Zone	≥65,000 Btu/hr and <110,000 Btu/hr	≤ 50%	January 1, 2015 to January 1, 2018
	≥ 110,000 Btu/hr	≤ 33%	
	≥65,000 Btu/hr	≤ 20%	After January 1, 2018
Multiple Zone	≥65,000 Btu/hr	≤ 25%	January 1, 2015 to January 1, 2018
	≥65,000 Btu/hr and <600,000 Btu/hr	≤ 20%	After January 1, 2018
	≥ 600,000 Btu/hr	≤ 10%	

[a]See Tables 112-A and 112-B for rating standard and conditions

Comment Responses

1. In the AHRI alternate proposal you use the terms constant volume units and variable volume units. We assume you really mean single zone units and multiple zone units, since all units with 2 speed or variable speed fans will be variable volume units.

2. Our proposal for fan control basically says the fan shall be capable of turning down to 66% speed for single zone and 50% for multiple zone but does not prescribe control sequences. The AHRI alternate proposal uses the same fan speeds but it also defines specific control sequences – e.g. fan must go to low speed when cooling demand is less than 50%. We feel

this is unnecessarily restrictive. For example, even if the cooling demand is less than 50% it might still be more efficient to run the fan above 50% speed to get more economizer cooling and keep the compressor offline.

3. We agree that going from 25% to 20% turndown on a large multiple zone system will not eliminate economizer cycling. The expectation, however, is that manufacturers will meet a 25% or lower requirement by converting one of the compressors to a variable capacity or variable speed compressor, as Carrier and Aaon have done on some of their large units. Manufacturers have told us that the cost to do this is minimal. A variable capacity or variable speed compressor on a unit with 4 compressors should provide a total turndown of about 5%, which will largely eliminate economizer cycling. In the long term, we propose lowering the turndown requirement below 25% for large units.

4. Slide 7 is used as evidence that economizer dampers do not have to cycle when compressors over cool. It is clear however, from the first figure that the economizer is reducing the return air from about 77°F to about 70°F and the first compressor further lowers the supply air temperature from 70°F to about 57°F ($\Delta T = 13^{o}F$). This simply indicates that the total load seen by the unit is quite high (close to full load) and the compressor is meeting about 65% of the load and the economizer is meeting about 35%. These are not the typical conditions under which the economizer will cycle. The economizer will cycle when the effective compressor load is say 25%, not 65%. The second figure simply shows that under the same high load conditions, the 2nd compressor overcools the supply air to 45°F. What this figure does not show is that the load has now been artificially raised due to the unnecessary additional latent cooling and that the total compressor efficiency is now lower. This also does not prove that the economizer on this unit will not cycle when the compressor load is low.

5. Similarly, Slide 8 does not prove that the economizer will not cycle. It just shows with a relatively high compressor load the economizer may not have to cycle but that the compressor will overcool the supply air.

6. One thing that is missing in the compressor efficiency curves on Slides 11 and 12 is the degradation in efficiency when the compressor overcools the supply air from say 55F to say 45F.

7. Slide 13 – "the proposal is for 65K and above and currently there is only 1 manufacturer who has a high tier products that was just introduced this month." Yes, McQuay recently introduced a variable speed unit in this range but Aaon has had units in this range with digital scrolls for several years. Furthermore, there are other manufacturers, like Carrier, that have units above and below this size so the technology and products are clearly available today and will be more so in 3 to 6 years, when the revised proposal takes effect.

8. Slide 14 – You have correctly identified a flaw in our analysis for integrated economizers. We applied the 25% economizer derate annually. It should not have been applied to economizer-only hours. We are re-running the analysis and expect to use the revised analysis to justify the revised proposal outlined above.

9. Slide 16 – Variable capacity compressors have all the functionality of fixed stage compressors and more so they can provide all the humidity control functions of fixed stage compressors and more. Variable capacity compressors could decrease humidity control if not controlled for humidity but they can also control humidity better than fixed stage compressors if controlled properly. For example, the fan speed does not have to be on high speed during economizer as stated in the second bullet on slide 16. The fan speed could be adjusted to maintain the desired supply air temperature for humidity control for the given load.

10. Slide 17 – SEER rating – Our analyses will be re-run using the 90.1-2010 equipment efficiencies for the various sizes of equipment covered in the revised proposal. For example, for large multiple zone units (≥240,000 Btu/h and <760,000 Btu/h) we will use 10.0 EER and 10.1 IEER.

11. Slide 17 - External static – We will re-run the analyses at a couple different external statics appropriate for the various sizes and types of equipment in question for the revised proposal. I doubt the results will be very sensitive to the external static.

12. Slide 18 – Conjecture on cost reductions are not used in the analysis. We are using the costs provided.

13. Slide 26 – You are correct that our CHW fan coil analysis assumed modulating CHW control, rather than on/off control. Please note, however, that the analysis was conservative in that it did not included the motor efficiency benefit of the EC motor or the fan heat savings. In fact, there is another proposal for Title 24-2013 to require EC motors on HVAC motors less than 1 HP and that proposal justifies the EC motor solely on motor efficiency savings. To be conservative, our analysis included the full incremental cost of EC motors using current costs ($182) and a conservative estimate for start-up/commissioning. We have talked to some local contractors who have estimated that the incremental cost for an analog thermostat versus a 2 stage thermostat is about $100. If we take the EC motor cost out of the analysis (since it is already justified by another proposal) or add the motor efficiency savings into the analysis then the extra $100 for the analog thermostat is easily justified.

We will contact you in the next day or two to arrange a conference call within the next week or so. We look forward to working together with you on this important proposal.

Sincerely,
Taylor Engineering LLC

Jeff Stein, P.E.
Principal